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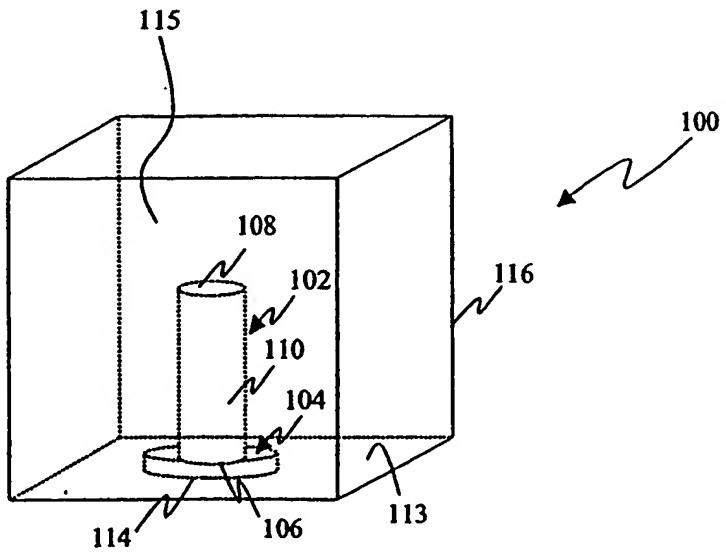

(57) Abstract: A dielectric resonator is provided. The dielectric resonator includes a rod having first and second ends and an exterior surface that extends between the first and second ends. The resonator also includes a base, coupled to the first end of the rod, the base being adapted to attach to an interior surface of a housing. The rod and the base comprise a dielectric material.

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DIELECTRIC RESONATOR

TECHNICAL FIELD

The present invention relates generally to the field of filters and, in particular, to a dielectric resonator for use in, for example, a cavity filter.

BACKGROUND

Wireless telecommunications systems transmit signals to and from wireless terminals using radio frequency (RF) signals. A typical wireless system includes a plurality of base stations that are connected to the public switched telephone network (PSTN) via a mobile switching center (MSC). Each base station includes a number of radio transceivers that are typically associated with a transmission tower. Each base station is located so as to cover a geographic region known colloquially as a "cell." Each base station communicates with wireless terminals, e.g. cellular telephones, pagers, and other wireless units, located in its geographic region or cell.

A wireless base station includes a number of modules that work together to process RF signals. These modules typically include, by way of example, mixers, amplifiers, filters, transmission lines, antennas and other appropriate circuits. One type of filter that finds increased use in wireless base stations is known as a microwave cavity filter.

A new type of resonator for a microwave cavity filter was proposed by Chi Wang, et al. in *Dielectric Combline Resonators and Filters*, IEEE Transactions on Microwave Theory and Techniques, Vol. 46, No. 12, December 1998. Wang et al. considered the use of a high ε_r dielectric rod in place of a conventional conductor of the resonators of the microwave cavity filter. Unfortunately, when a dielectric rod is used in the resonators, an unacceptable level of insertion loss is experienced using conventional approaches.

For the reasons stated above, and for other reasons stated below which will become apparent to those skilled in the art upon reading and understanding the present specification, there is a need in the art for a filter with a dielectric resonator that provides lower levels of insertion loss.

SUMMARY

The above mentioned problems with cavity filter is having a dielectric resonator rod and other problems are addressed by embodiments of the present invention and will be understood by reading and studying the following specification. Embodiments of the present invention provide a resonator rod for the cavity filter that includes a base portion that allows the resonator rod to be attached to the inside of the cavity without substantial adverse effects on the insertion loss of the filter.

More particularly, in one embodiment a dielectric resonator is provided. The dielectric resonator includes a rod having first and second ends and an exterior surface that extends between the first and second ends. The resonator also includes a base, coupled to the first end of the rod, the base being adapted to attach to an interior surface of a housing. The rod and the base comprise a dielectric material.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a perspective view that represents an embodiment of a dielectric resonator according to the teachings of the present invention.

Figure 2 is a perspective view that represents another embodiment of a dielectric resonator according to the teachings of the present invention.

Figure 3 is graph that depicts an example of electric fields in a Y-Z plane for an embodiment of a dielectric resonator according to the teachings of the present invention.

Figures 4, 5, 6, 7, 8, and 9 are cross sectional views that illustrate various alternative embodiments of an attachment mechanism for attaching a dielectric rod within a housing according to the teachings of the present invention.

Figures 10, 11, and 12 are perspective views of additional embodiments of a dielectric resonator according to the teachings of the present invention.

Figure 13 is a perspective view of a filter including a plurality of dielectric resonators according to the present invention.

DETAILED DESCRIPTION

In the following detailed description, reference is made to the accompanying drawings that form a part hereof, and in which is shown by way of illustration specific illustrative embodiments in which the invention may be practiced. These embodiments are described in sufficient detail to enable those skilled in the art to practice the invention, and it is to be understood that other embodiments may be utilized and that logical, mechanical and electrical changes may be made without departing from the spirit and scope of the present invention. The following detailed description is, therefore, not to be taken in a limiting sense.

I. Resonator Structure

Figure 1 is a perspective view that represents an embodiment of a dielectric resonator, indicated generally at 100, according to the teachings of the present invention. Dielectric resonator 100 includes rod 102 and base 104. Rod 102 and base 104 are each constructed of a dielectric material. In one embodiment, rod 102 and base 104 are separately formed of ceramic material. In another embodiment, rod 102 and base 104 are formed simultaneously using an appropriate pressing tool.

Rod 102 has first and second opposite ends 106 and 108 and an exterior surface 110 that extends between the first and second ends 106 and 108. In one embodiment, rod 102 comprises a cylindrical rod, as shown. In other embodiments, rod 102 comprises other appropriate shapes.

Base 104 is attached to first end 106 of rod 102. In one embodiment, base 104 is sintered to rod 102. In other embodiments, base 104 and rod 102 are formed at the same time in a single pressing process.

Figure 2 illustrates another embodiment of a dielectric resonator, indicated generally at 200. Dielectric resonator 200 includes rod 202 and base 204. In one embodiment, rod 202 and base 204 are formed in a single pressing motion in the direction of arrow 212. In another embodiment, rod 202 and base 204 are formed separately and then sintered together.

Base 104 provides an attachment surface 114 for attaching rod 102 to interior surface 113 in cavity 115 of housing or enclosure 116. In one embodiment, base 104 is smaller than interior surface 113 of housing 116. Advantageously, rod 102 and

base 104 are secured in place by an attachment mechanism coupled to base 104 that reduces losses caused by conventional attachment mechanism associated with the end of a dielectric rod. Example embodiments of attachment mechanisms that can be used to secure base 104 in cavity 115 are illustrated in Figures 4-9, which Figures are described in detail below.

Conventionally, lossy fixing materials, e.g., epoxy, are used to secure the end of a rod to the interior surface of a housing. Unfortunately, these materials can considerably reduce the Q-value of the resonator when applied to the end of the rod where the electric fields are typically quite strong. By using base structures such as those shown in Figures 1 and 2, embodiments of this invention advantageously reduce the affect of the fixing material on the Q-value of the resonator by moving the lossy fixing materials away from the rod where electric fields are weaker. This is illustrated in Figure 4. Figure 4 is a simulation generated with Ansoft HFSS Version 7.0.04 that illustrates the relative strength of electrical fields in the Y-Z plane in base 104 and rod 102. The strength of the electric fields in region 400 of base 104 are lower than the fields in rod 102. Thus, the affect of the lossy fixing materials on the Q-value of the resonator is substantially reduced.

Base 104 is wider than rod 102. In the embodiment of Figure 1, base 104 and rod 102 comprise concentric structures with the width of base 104 exceeding the width of rod 102. In other embodiments, the base does not extend around the entire perimeter of the rod. For example, in the embodiment of Figure 2, base 204 extends in a direction (N) normal to surface 110 on opposite sides of rod 202. In both Figure 1 and Figure 2, each base 104, 204 provides an attachment surface 114, 214 that lie outside a planar projection of rod 102, 202 on the interior surface 113, 213 of the housing 116, 216. It is understood that other shapes for the base may be substituted that allow the lossy attachment mechanism to be moved out away from the end of the rod. The size of base 104 does not adversely affect spurious properties of resonator 100 so long as its radius is not too large with respect to the radius of rod 102. For purposes of this specification, the term spurious properties means the affect of signals at frequencies in unused modes that affect frequency response properties outside the passband of a filter incorporating the resonator.

II. Attachment Mechanisms

Figures 4, 5, 6, 7, 8, and 9 are cross sectional views that illustrate various alternative embodiments of an attachment mechanism for attaching a dielectric rod within a housing according to the teachings of the present invention. Each of the embodiments is described in turn.

In Figure 4, rod 402 and base 404 are coupled to surface 413 using an adhesive 420 such as an epoxy resin. It is understood that adhesive 420 comprises, in other embodiments, other appropriate substances, compounds and glues with a low dissipation factor that are capable of affixing a ceramic material to a metal surface. In this embodiment, adhesive 420 is applied to attachment surface 414 along its perimeter 422.

In Figure 5, rod 502 and base 504 are coupled to surface 513 using attachment mechanism 520. In this embodiment, attachment mechanism 520 includes at least two screws 524 and collar 526. Collar 526 includes surface 528 that engages base 504 between collar 526 and surface 513. Screws 524 pass through collar 526 and into surface 513. In one embodiment, collar 526 encompasses the entire perimeter of base 504. In other embodiments, collar 526 comprises multiple collars with each collar engaging only a portion of the perimeter of base 504. In one embodiment, collar 526 and screws 524 comprise a plastic material. In other embodiments, collar 526 and screws 524 comprise a dielectric material.

In Figure 6, rod 602 and base 604 are coupled to surface 613 using attachment mechanism 620. In this embodiment, attachment mechanism 620 includes a plurality of screws through base 604 into surface 613. In one embodiment, the screws of attachment mechanism 620 comprise plastic screws. In other embodiments, attachment mechanism 620 comprises screws of any other appropriate material for use in a resonator housing, e.g., any appropriate dielectric material.

In Figure 7, rod 702 and base 704 are coupled to surface 713 using any of the attachment mechanisms of Figures 5, 6, 8, and 9. In this embodiment, air cavity 720 is provided under base 704. It is noted that the presence of the air cavity shifts the resonant frequency of the resonator, but does not substantially affect the Q value of

the resonator. Figure 7 illustrates that base 704 provides the advantages of reduced insertion loss even though base 104 is attached to an uneven surface.

In Figure 8, rod 802 and base 804 are coupled to surface 813 using attachment mechanism 820. In this embodiment, attachment mechanism 820 includes dielectric a plurality of supports 822. In one embodiment, two or more supports 822 are dispersed around the perimeter of base 804. Supports 822 are affixed to surface 813 using, for example, an adhesive. It is noted that the resonator performance is improved with the use of attachment mechanism 820 even though the bottom of resonator rod 802 is separated by a distance from surface 813.

In Figure 9, rod 902 and base 904 are coupled to surface 913 using attachment mechanism 920. In this embodiment, attachment mechanism 920 includes a plurality of protuberances or posts 924 that are selectively spaced around region 930 of surface 913 for receiving base 904. In one embodiment, the plurality of posts comprises four posts spaced apart around base 904. In other embodiments, any appropriate number of posts 924 are used that allow base 904 to be securely held in place on surface 913. Base 904 is secured in place by adhesive 922 between base 904 and posts 924. In one embodiment, posts 924 comprise a single ridge that encircles the perimeter of base 904.

III. Alternative Resonator Rods

Figures 10, 11, and 12 are perspective views of additional embodiments of a dielectric resonator according to the teachings of the present invention. The structures of these resonators are designed to allow the resonator to be shortened to allow use with a smaller cavity. In Figure 10, metal plate 1040 is attached to second end 1008 opposite base 1004 attached to first end 1006 of rod 1002. In Figure 11, ceramic body 1140 is attached to second end 1108 opposite base 1104 attached to first end 1106 of rod 1102. In Figure 12, ceramic body 1240 is attached to second end 1208 opposite base 1204 attached to first end 1206 of rod 1202.

IV. Filter

Figure 13 is a partially exploded perspective view of a filter, indicated generally at 1300, including a plurality of dielectric resonators 1350-a, 1350-b, and

1350-c according to the present invention. Advantageously, each of resonators 1350-a, 1350-b, and 1350-c includes a base of the type described above with respect to Figures 1 and 2 that allows the resonators to be affixed in cavities 1352-a, 1352-b, and 1352-c with reduced losses caused by conventional attachment mechanism associated with the end of a dielectric rod. Further, resonators 1350-a, 1350-b, and 1350-c are each affixed to surface 1354 in housing 1356 using, for example, one or more of the attachment mechanisms of Figures 4-9.

Filter 1300 also includes lid 1358 that is selectively attached to housing 1356. Lid 1358 includes tuning screws 1360-a, 1360-b, and 1360-c that are associated with resonators 1350-a, 1350-b, and 1350-c, respectively. Tuning screws 1360-a, 1360-b, and 1360-c are used to adjust the passband of filter 1300. Lid 1358 further includes tuning screws 1362-a and 1362-b that adjust the coupling between cavities 1352-a, 1352-b and 1352-b, 1352-c, respectively.

Filter 1300 also includes input 1364 and output 1366. Input 1364 receives an input signal for filtering by filter 1300. The filtered output of filter 1300 is provided at output 1366.

V. Materials

The resonators of the various embodiments include rods, bases and other components that are formed of dielectric materials, such as ceramic materials. In one embodiment, the dielectric materials comprise materials with a dielectric constant, ε_r, of about 45, for example, with low dielectric losses. It is understood that materials with other dielectric constants can also be used. Further, the various dielectric elements, in some embodiments, are produced with commercially available ceramic materials such as 4500 series ceramic material from Trans-Tech, Inc., Adamstown, MD or K4500 ceramic material from EDO Electro-Ceramics, Salt Lake City, UT.

Conclusion

Embodiments of the present invention have been described. The embodiments provide a dielectric resonator with a base for attaching the resonator rod within a housing. The base is designed such that the attachment mechanism

reduced losses caused by conventional attachment mechanism associated with the end of a dielectric rod. For example, the base in one embodiment has a diameter that is greater than the diameter of an end of the resonator rod. Other embodiments are also provided that provide a base with an attachment surface that is outside the planar projection of the rod on the surface of the housing.

Although specific embodiments have been illustrated and described in this specification, it will be appreciated by those of ordinary skill in the art that any arrangement that is calculated to achieve the same purpose may be substituted for the specific embodiment shown. This application is intended to cover any adaptations or variations of the present invention. For example, the dielectric material used for the base and the rod can be varied. Further, the base can be used with any appropriate resonator structure for single mode or multimode resonators.

What is claimed is:

1. A resonator, comprising:

an enclosure having a cavity;

a dielectric rod, disposed in the cavity, the dielectric rod having a width; and

a base, adapted to connect the dielectric rod with the enclosure, the base having a second width that is greater than the width of the dielectric rod.

2. The resonator of claim 1, wherein the base portion extends around substantially the entire perimeter of the dielectric rod.

3. The resonator of claim 1, wherein the base portion is attached to the cavity by an adhesive.

4. The resonator of claim 1, wherein the adhesive has a low dissipation factor.

5. The resonator of claim 1, wherein the base portion is attached to the cavity by a plurality of screws.

6. The resonator of claim 1, wherein the dielectric rod comprises a ceramic rod.

7. A method of forming a resonator, the method comprising:

forming a housing having a cavity;

forming a dielectric rod;

forming a dielectric base attached to the dielectric rod; and

attaching the dielectric base on a surface within the cavity of the housing.

8. The method of claim 7, wherein forming a dielectric rod comprises forming a ceramic rod.

9. The method of claim 7, wherein forming a dielectric rod and forming a dielectric base comprise forming the dielectric rod and dielectric base in a single pressing process.

10. The method of claim 7, wherein forming the dielectric rod and forming the dielectric base comprise:

forming the dielectric rod;

separately forming the dielectric base; and

sintering the dielectric base to the dielectric rod.

11. The method of claim 7, wherein attaching the dielectric base on a surface comprises attaching the dielectric base on the surface with at least one of adhesive around at least a portion of a perimeter of the base, at least two screws, a collar, a dielectric support that engages a surface of the base, and a plurality of protuberances disposed around a perimeter of the base.

12. A dielectric resonator, comprising

a rod having first and second ends and an exterior surface that extends between the first and second ends;

a base, coupled to the first end of the rod, the base being adapted to attach to an interior surface of a housing; and

wherein the rod and the base comprise a dielectric material.

13. The dielectric resonator of claim 12, wherein the rod and the base comprise a ceramic material.

14. The dielectric resonator of claim 12, wherein the base extends in a direction normal to at least a portion of the exterior surface of the rod.

15. The dielectric resonator of claim 12, wherein the base has a diameter that is wider than the diameter of the first end of the rod.

16. The dielectric resonator of claim 12, wherein the base provides an attachment surface that lies at least in part outside a projection of the first end of the rod on the interior surface of the housing.

17. The dielectric resonator of claim 12, wherein the base is smaller than the interior surface that the base is attached to.

18. The dielectric resonator of claim 12, wherein the rod includes a second resonator portion attached to the second end of the rod.

19. The dielectric resonator of claim 18, wherein the second resonator portion comprises one of a metal plate, and a dielectric block.

20. A resonator, comprising:

a housing having a cavity with an interior surface;

a dielectric body having first and second ends and an exterior surface that extends between the first and second ends;

a dielectric base, coupled to the first end of the dielectric body, wherein the dielectric base includes an attachment surface that is normal to at least a portion of the exterior surface of the dielectric body; and

an attachment mechanism that couples the attachment surface of the dielectric base to the interior surface of the housing.

21. The resonator of claim 20, wherein the dielectric body and the dielectric base each comprise a ceramic material.

22. The resonator of claim 20, wherein the attachment mechanism comprises at least one of screws, adhesive, a collar, a dielectric support, and protuberances.

23. A filter, comprising:

an input adapted to receive an RF signal;

an output adapted to provide a filtered RF output signal; and

a plurality of dielectric resonators coupled in series between the input and the output to process the received RF signal and to produce the filtered RF output signal, each dielectric resonator including:

a rod having first and second ends and an exterior surface the extends between the first and second ends;

a base, coupled to the first end of the rod, the base being adapted to attach to an interior surface of a housing; and

wherein the rod and the base comprise a dielectric material.

24. The filter of claim 23, wherein the rod and the base comprise a ceramic material.

25. The filter of claim 23, wherein the base extends in a direction normal to at least a portion of the exterior surface of the rod.

26. The filter of claim 23, wherein the base has a diameter that is wider than the diameter of the first end of the rod.

27. The filter of claim 23, wherein the base provides an attachment surface that lies at least in part outside a projection of the first end of the rod on the interior surface of the housing.

28. The filter of claim 23, wherein the base is smaller than the interior surface that the base is attached to.

29. The filter of claim 23, wherein the rod includes a second resonator portion attached to the second end of the rod.

30. The filter of claim 29, wherein the second resonator portion comprises one of a metal plate, and a dielectric block.

31. The filter of claim 23, and further including an attachment mechanism for attaching the base to the interior surface of a housing.

32. The filter of claim 31, wherein the attachment mechanism comprises at least one of screws, adhesive, a collar, a dielectric support, and protuberances.

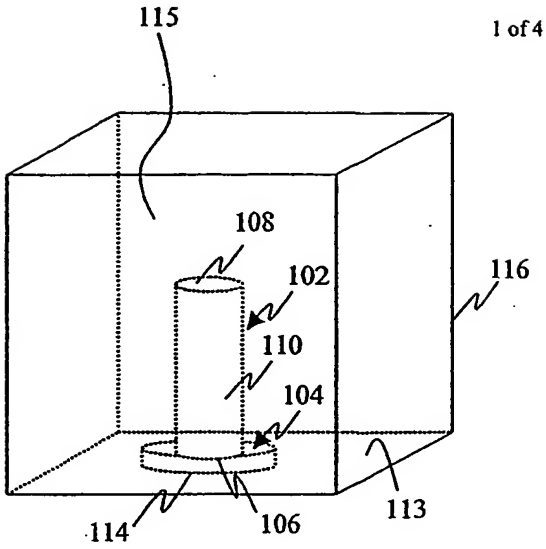


FIG. 1

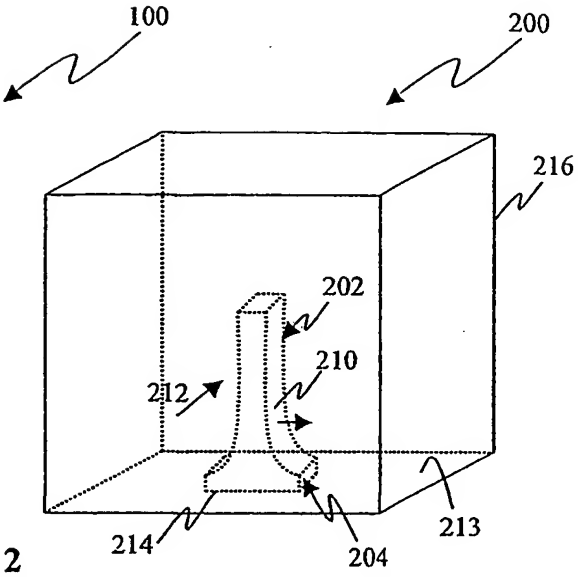


FIG. 2

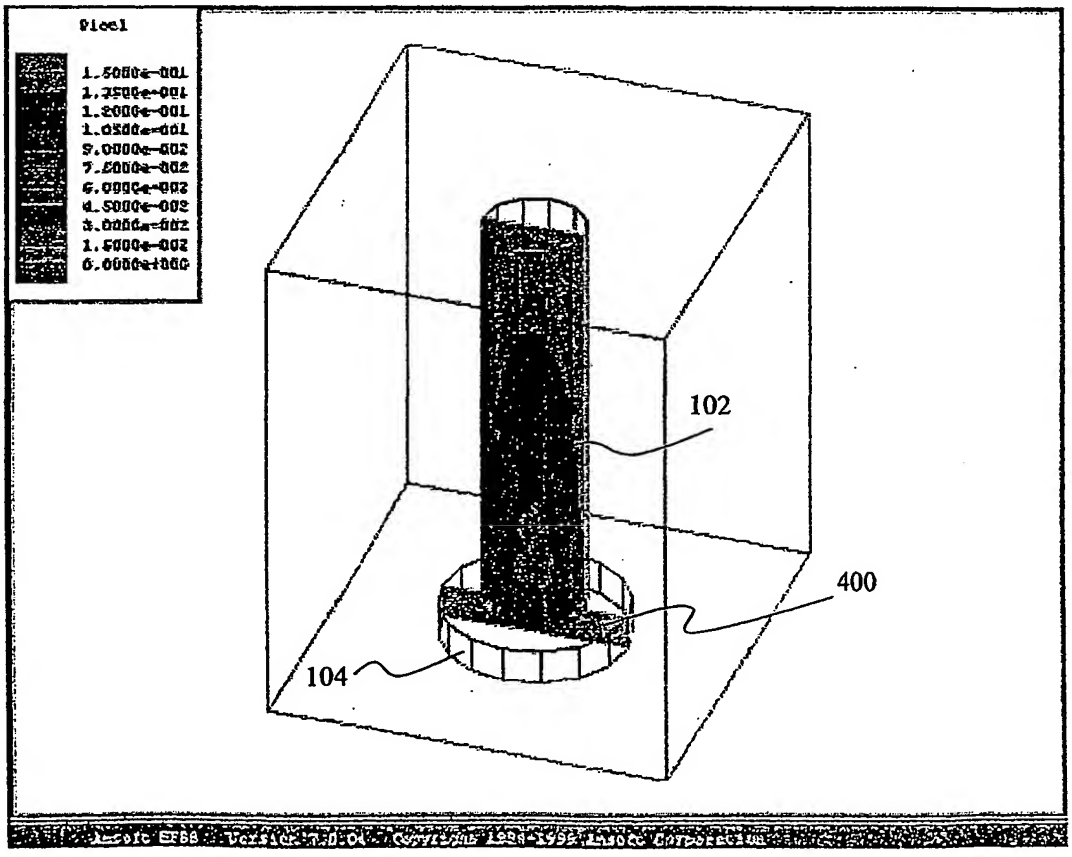


FIG. 3

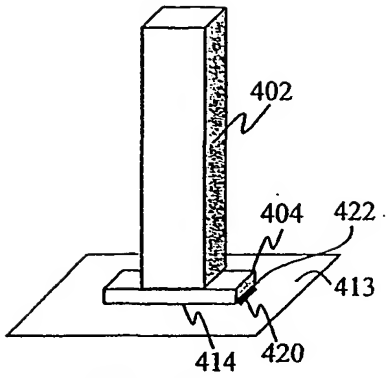


FIG. 4

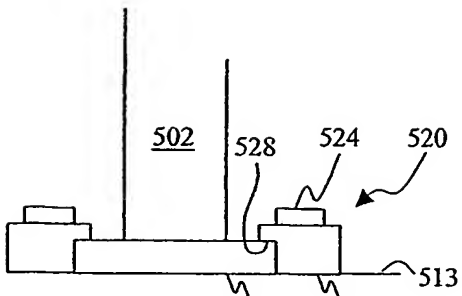


FIG. 5

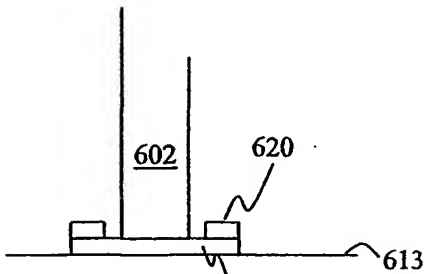


FIG. 6

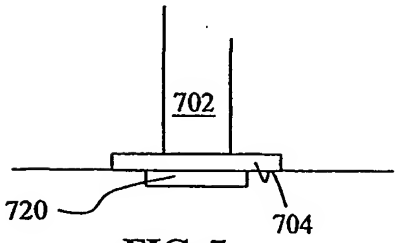


FIG. 7

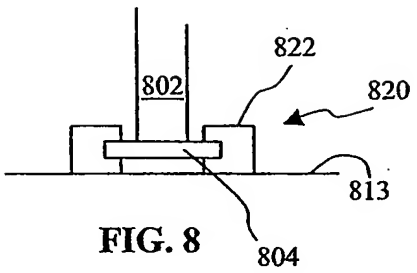


FIG. 8

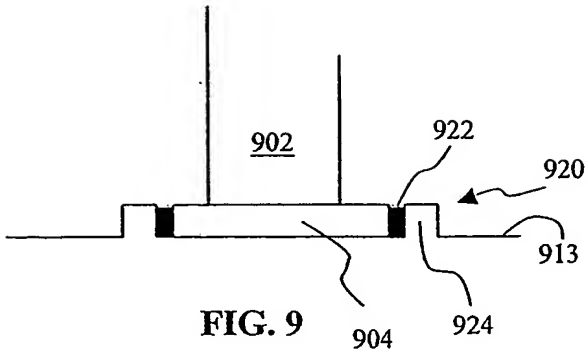


FIG. 9

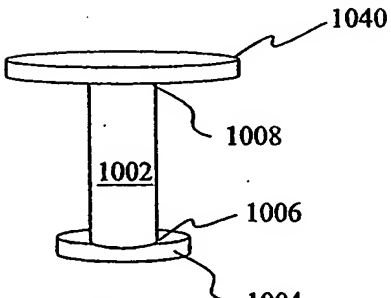


FIG. 10

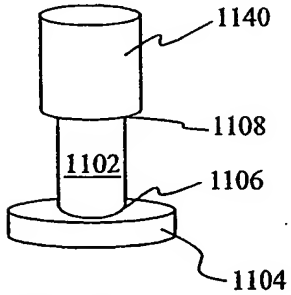


FIG. 11

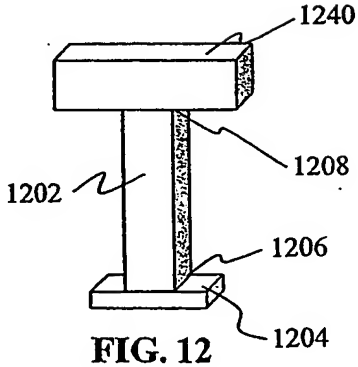
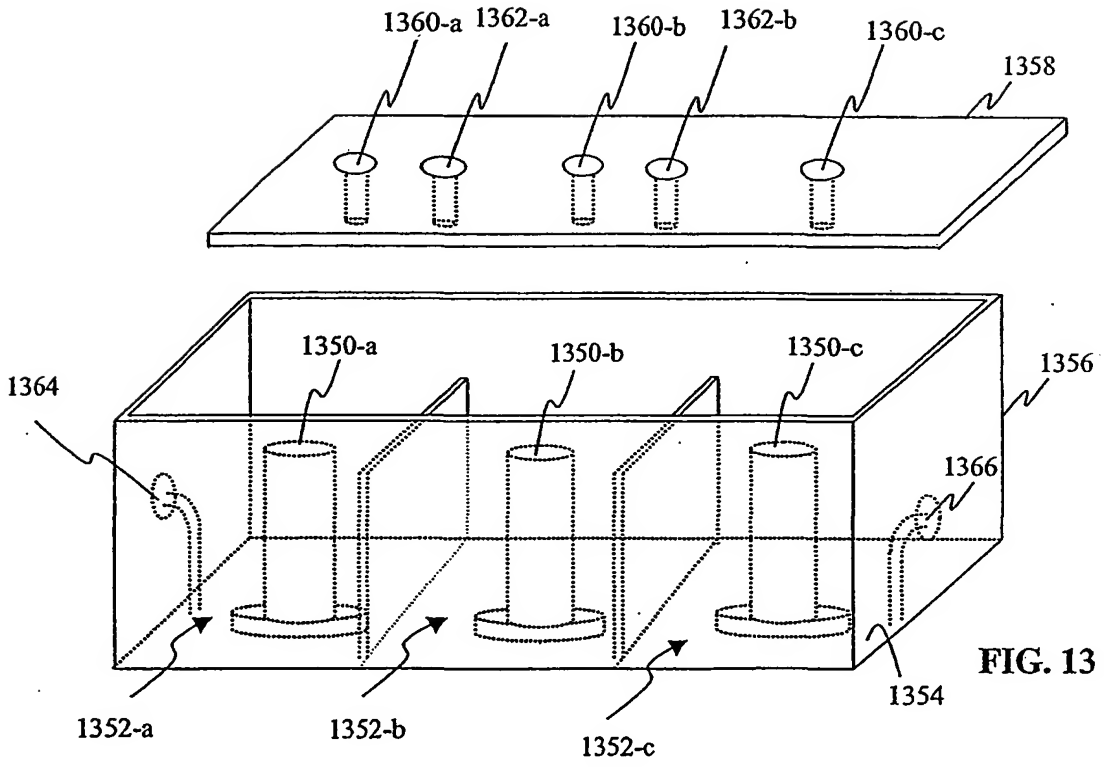


FIG. 12


1360-a
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1352-a
1352-b
1352-c

FIG. 13

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 01/47117

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H01P1/208 H01P7/10

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H01P

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
PAJ, EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	PATENT ABSTRACTS OF JAPAN vol. 009, no. 008 (E-289), 12 January 1985 (1985-01-12) -& JP 59 158601 A (NIPPON DENKI KK), 8 September 1984 (1984-09-08) abstract	1,3,7, 11,12, 14-17, 20,22
Y		2,4-6,8, 9,13,18, 19,21
Y	PATENT ABSTRACTS OF JAPAN vol. 006, no. 052 (E-100), 7 April 1982 (1982-04-07) -& JP 56 165402 A (NEC CORP), 19 December 1981 (1981-12-19) abstract; figures 1-3	2,9

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
11 March 2002	20/03/2002

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European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Den Otter, A

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INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 01/47117

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